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Gastric Bioaccessiblity Of Iron Fortified Maize Meal Products.

D.Chinofunga[1], D. Jaravaza[2], T. Usai[3], I. Matiringe[4], J.H. Serere[5]
1(Department of Applied Education: Food Technology and Design, P. Bag 9055, Gweru, Zimbabwe)
2(Department of Food Science and Nutrition, P. Bag 9055,Gweru, Zimbabwe)
3(Department of Applied Education: Food Technology and Design, P. Bag 9055, Gweru, Zimbabwe)
4(Department of Food Science and Nutrition, P. Bag 9055, Gweru, Zimbabwe)
5(Department of Food Science and Nutrition, P. Bag 9055, Gweru, Zimbabwe)
Corresponding Author: D.Chinofunga

Abstract: The main focus of this study was to evaluate the bioaccessibility of iron in iron fortified maize meal products commonly consumed in Zimbabwe and its possible contribution to iron Recommended Daily Allowance (RDA) in the vulnerable population. The maize meal was fortified with a 2.5 mg/100g Sodium iron (III) ethylenediamineteracetate (NaFe EDTA). Samples were drawn from various maize products Sadza, plain porridge, sour porridge and mahewu for biochemical analyses. In this study Lutens in vitro solubility method was used to compare the bioaccessibility of iron in maize secondary products. Inductively coupled plasma-optical emission spectrometer was used to assess total iron content in all samples. All analyses were done according to analytical Standards. A significant difference in iron bioaccessibility ($p<0.05$) was observed among all maize meal products. Total iron content and iron bioaccessibility range between 1.73 to 2.14mg/100g and 1.00 to 1.90 mg/100g respectively. It was also observed that iron bioaccessibility was significantly high in fermented products compared to non-fermented products. This therefore means that fortification of maize meal has a potential to significantly reduce iron deficiency and its resultant iron deficiency anaemia in the vulnerable Zimbabwean population.

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I. INTRODUCTION

Anaemia is defined as the peripheral blood haemoglobin level below the normal range expected for particular age and sex of an individual [1]. Fifty percent of all anaemia cases are caused by insufficient dietary intake and absorption of iron [2]. However, other common causes include vitamin A deficiency, intestinal parasitic worms in children, iron loss from bleeding [3]. Iron deficiency pose serious health consequences which include increased maternal and child morbidity and mortality, chronic anaemia, and physical development in children and reduced work productivity in adults [4]. Iron deficiency anaemia continues to be a public health problem of concern and major cause of ill health in Zimbabwe. Statistics shows that 72% of children between 6-59 months are iron deficient and 31% are anaemic while 26% women of child bearing age are anemic[5]. Statistics also showed that nearly 1.5 million working age adults with anaemia suffer deficits in work performance [6]. The optimal dietary iron consumption is 18mg/day [7]. However the recommended daily allowance (RDA) may vary in individuals according to sex, age and physiological state and may range from 18mg/day to 27mg/day [2]. Food fortification is the most common and preferred intervention used to address anaemia prevalence in developing countries [8]. A fortification vehicle commonly consumed by the target population is identified and then fortified with the desired micronutrient(s). In Zimbabwe maize is the staple food as more than 77% of it is used for human consumption [9.] Fortifying maize meal with iron that will be bioaccessible in maize secondary products is a positive step in mitigating iron deficiency and its resultant iron deficient anaemia in Zimbabwe and other countries where maize products are consumed in large quantities as a staple food[10]. It is therefore important to determine the bioaccessibility of iron in secondary maize meal products made from iron fortified maize meal to determine the efficacy of the recently proposed National food fortification Strategy which was launched in November 2015 in Zimbabwe in addressing iron deficiency in the country[11].

II. METHODS

This study was an exploratory study design used to obtain quantitative data. The population of the study comprised of fortified maize meal products which consisted of four sub-populations: mahewu, sour porridge, plain porridge, and Sadza. Experiments were carried out on all the selected products total iron content, iron bioaccessibility and possible percentage contributions to iron RDA in all fortified products was investigated so as to relate the differences if any to the success of the Proposed National food fortification strategy. Simple systematic sampling was used to sample the population.

Sample A
Sample A comprised of maize meal fortified with NaFeEDTA. The sample was tested for total iron content and iron bioaccessibility.
Sample B
This sample comprised of iron fortified maize mahewu brewed in the laboratory. The sample was tested for pH, total iron content and iron bioaccessibility. The sample was drawn from the final product after fermentation.
Sample C
This sample was sour porridge made from iron fortified maize meal, sugar, salt and water. Samples were obtained from the final product after fermentation and were analyzed for iron content and iron bioaccessibility.
Sample D
Sample D comprised of plain porridge (non-fermented) made from fortified maize meal, sugar, and salt. Samples were drawn from the final product and were tested for total iron content iron bioaccessibility.
Sample E
Sample E comprised of Sadza prepared from iron fortified maize meal in the laboratory. The sample was drawn from the final product after cooking and was analyzed for iron content and iron bioaccessibility.
Determination of iron content and iron bioaccessibility was done according to a method by Kiers, Nout and Rombouts, [12]. All analytical procedures were done with well calibrated equipment (for validity) and non-iron coated apparatus were used (to avoid cross contamination). Samples were prepared using maize fortified with NaFeEDTA in the laboratory for analysis

Total iron content and in vitro Bioaccessibility

Iron content of the NaFeEDTA fortified maize meal was analyzed using an Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) in a method by A.O.A.C, (2012)[13]. In vitro bioaccessibility of iron in iron fortified maize products was determined and quantified using the in vitro solubility analysis assay as described by Kiers et al, [12]). Samples of maize products (5g) were digested under simulated stomach conditions. Digestive enzymes Pepsin (P-700), pancreatin (P-1750) and bile extract (B-8631) procured from Sigma Aldrich (Johannesburg, South Africa) were used. Sample digestion were carried out at 37°C to simulate body temperatures. All digests were centrifuged at 3500g using a Labofuge 400 heraeus centrifuge to yield a supernatant which was then filtered through a 0.45 mm filter and used to represent the soluble iron. Iron concentration in supernatant was determined using an ICP-OES (Spectro Arcos, Kleve, Germany). The amount of iron in the supernatant was regarded as the bioaccessible (soluble) iron. Working iron standard solutions were prepared by diluting stock standard solution (1000 mg/l, Merck, Germany) to the desired concentrations. The calibration ranges for standard solutions were selected to match expected concentrations of iron in the samples to be analyzed by ICP-OES. Percentage solubility of iron was calculated as the amount of soluble compound relative to the total amount of compound in the test sample.

Statistical analysis

Bioaccessibility %=amount of Fe (supernatant) – amount of Fe (blank)\ amount of Fe (undigested sample) ×100. Graph Pad Prism 4 and Excel 2013 were used to carryout analysis of variance (ANOVA) on the data observed and graphical representation of the results where variations were observed among the samples at 95% ($p<0.05$) statistical significance.

III. RESULTS

Iron Bioaccessibility

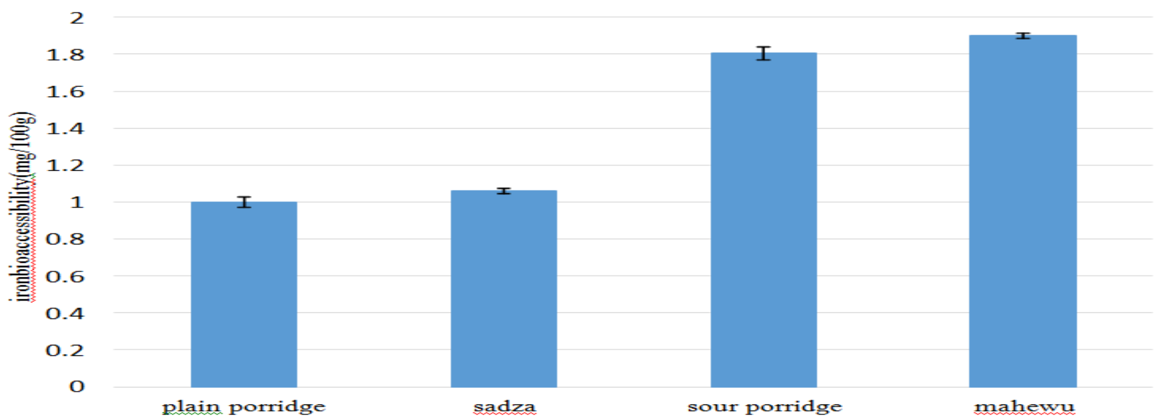

Figure no 1: Bioaccessibility of iron in various maize meal products commonly consumed in Zimbabwe. Figure no 1 indicates that bioaccessible iron was high in mahewu (1.9mg/100g) and sour porridge (1.8mg/100g) (fermented products) and less accessible in plain porridge(1mg/100g) and Sadza (1.1 mg/100g)(non-fermented products). The results shows that all the four products contained bioaccessible iron.

Percentage of Iron Bioaccessibility

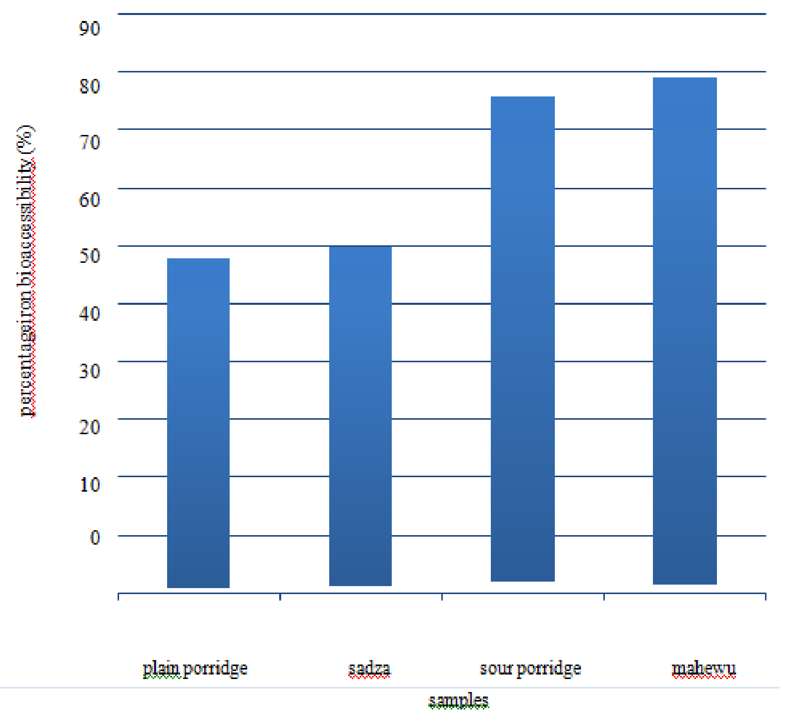

Figure no 2: Percentage iron Bioaccessibility in various iron fortified maize products.

Figure no 2 illustrates that fermented foods sour porridge and mahewu had the highest amount of bioaccessible iron with 85.75 and 88.95% respectively and the least was recorded in plain Sadza and porridge (non-fermented) with 58% and 59.95% respectively. Iron in all samples was bioaccessible.

Possible contribution to Iron RDA

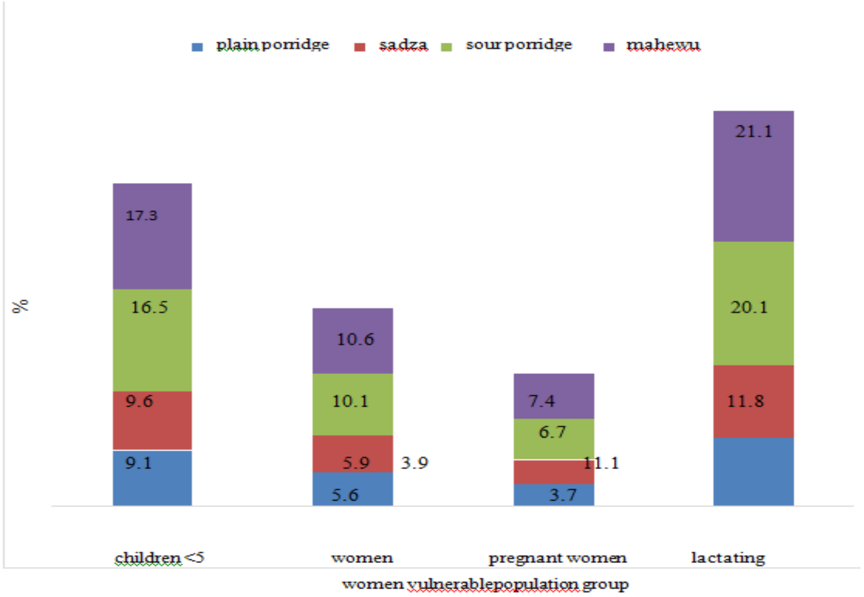

Figure no 3: The possible contribution of various maize meal products to RDA for iron.

The graph indicates the possible contribution of various iron fortified maize meal products to RDA for iron for the vulnerable population (children below 5 years, women, pregnant women and lactating women). It was noted that lactating women might benefit more with pregnant women being the lowest benefactor. Mahewu contribute the highest with a possible maximum of 21.1% while plain porridge contribute the lowest with a possible maximum contribution of 3.7%.

IV. DISCUSSION

The study focused on assessing the bioaccessibility of iron in various iron fortified maize meal products and their contributions on iron RDA in vulnerable Zimbabwean populations. The total iron content was determined in the different maize meal products after processing. In general the total iron content of fortified maize meal after fortification was below 2.5 mg/100g, the initial iron content added to the maize meal during fortification. This resonates with the findings by Salvador (2015) who observed a decrease in total iron content during fortification of cassava mahewu with ferrous sulfate and ferrous fumarate respectively[3]. This was also the case observed by (Ikpeme-Emmanuel *et al*., 2011) who fortified gari and Fufu (cassava meals) with 20mg/100g ferrous Sulfate (FeSO4) [14]. These were shown after processing to have an iron content of 10.70mg/100g (FeSO4) for gari and for fufu of 13.40mg/100g (FeSO4). The iron content detected in this current study for different maize meal samples ranged between 1.56 mg/100g and 2.89 mg/100g which is higher than that of non-fortified maize meal which ranges at 0.35mg to1.9mg/100g.

Mineral bioaccessibility refers to the amount of mineral(s) released from a food matrix in the gastrointestinal tract which is in the right form to be absorbed [15]. In this current study iron bioaccessibility was expressed as mg/100g sb (soluble) iron in the sample. There was a significant difference ($p<0.05$) in iron bioaccessibility among all four iron fortified samples. Mahewu showed the most bioaccessible iron with 1.90mg/100g followed by sour porridge with1.81mg/100g, Sadza with 1.06mg/100g and the least bioaccessible iron was recorded in plain porridge at 1.00mg/100g. The difference in bioaccessibility may be attributed to the pre-treatment processing (fermentation) as it is known to cause changes in physicochemical and functional characteristics of maize meal [15,16,17]**.** In this study, the fermented maize products (sour porridge and mahewu) had a significantly higher iron content and relative iron bioaccessibility when compared to non-fermented products. This is also in concordance with findings by Hurrel *et al*., 2003 who reported a significant increase in percentage iron bioaccessibility in fermented sorghum slurry versus a non-fermented slurry[18]. The difference in iron content and iron bioaccessibility between fermented and non-fermented products may be due to decreases in phytic acid content during fermentation [19]. In this study, 100g of maize meal products was used as the edible portion (serving). The percentage contribution of the various products was calculated using the RDA of iron for children below five years, women, pregnant women and lactating women. Iron fortified maize meal products can contribute significantly to iron RDA. 100g of the maize products investigated in this study would be sufficient to provide between 5% and 38% of RDA. This is in contrast with previous studies by Salvador, 2016 and Ikpeme-Emmanuel *et al*., 2011 who observed a lower possible iron RDA contribution of 6 to 12.3 % and 6 to 14% respectively in 100g of iron fortified cassava meals [3,14]. The differences in percentage contributions to RDA may be attributed to the different iron salts used for fortification in these studies. The highest contributions to iron RDA in this current study were observed only in fermented products. This is also in sync with previous studies by Salvador, 2016, Ikpeme-Emmanuel *et al*., 2011 who also observed high contribution in *gari, fufu*, mahewu and fermented slurry respectively, all of which are fermented products[3,14]. This may be attributed to increases in iron solubilities during fermentation

V. CONCLUSIONS

From the findings, it was concluded that all maize meal products made from iron fortified maize meal commonly consumed in Zimbabwe will contribute significantly to daily dietary iron intake in the vulnerable population. The iron fortified maize meal products will contribute between 5% and 38% iron to RDA. It was also noted that fermented maize products have a greater contribution to iron RDA among all maize meal products. Thus fortification of maize meal with NaFeEDTA has the potential to significantly reduce iron deficiency in the country.

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